

In the wood pulping industry, trees are conventionally classified as either hardwood or softwood. In the practice of the present invention, pulp for use as starting material in the practice of the present invention can be derived from softwood tree species such as, but not limited to: fir (preferably Douglas fir and Balsam fir), pine (preferably Eastern white pine and Loblolly pine), spruce (preferably White spruce), larch (preferably Eastern larch), cedar, and hemlock (preferably Eastern and Western hemlock). Examples of hardwood species from which pulp useful as a starting material in the present invention can be derived include, but are not limited to: acacia, alder (preferably Red alder and European black alder) aspen (preferably Quaking aspen), beech, birch, oak (preferably White oak), gum trees (preferably eucalyptus and Sweetgum), poplar (preferably Balsam poplar, Eastern cottonwood, Black cottonwood and Yellow poplar), gmelina and maple (preferably Sugar maple, Red maple, Silver maple and Bigleaf maple).

Wood from softwood or hardwood species generally includes three major components: cellulose, hemicellulose and lignin. Cellulose makes up about 50% of the woody structure of plants and is an unbranched polymer of D—glucose monomers. Individual cellulose polymer chains associate to form thicker microfibrils which, in turn, associate to form fibrils which are arranged into bundles. The bundles form fibers which are visible as components of the plant cell wall when viewed at high magnification under a light microscope. Cellulose is highly crystalline as a result of extensive intermolecular and intermolecular hydrogen bonding.

The term hemicellulose refers to a heterogeneous group of low molecular weight carbohydrate polymers that are associated with cellulose in wood. Hemicelluloses are amorphous, branched polymers, in contrast to cellulose which is a linear polymer. The principal, simple sugars that combine to form hemicelluloses are: D—glucose, D—xylose, D—mannose, L—arabinose, D—galactose, D—glucuronic acid and D—galacturonic acid.

Lignin is a complex aromatic polymer and comprises about 15% to 30% of wood where it occurs as an amorphous polymer.

In the pulping industry, differences in the chemistry of the principal components of wood are exploited in order to purify cellulose. For example, heated water in the form of steam causes the removal of acetyl groups from hemicellulose with a

corresponding decrease in pH due to the formation of acetic acid. At elevated temperatures of about 150°C-180°C, acid hydrolysis of the carbohydrate components of wood then ensues, with a lesser hydrolysis of lignin. Hemicelluloses are especially susceptible to this acid hydrolysis, and most of the hemicellulose can be degraded by an initial steam, prehydrolysis step in the Kraft pulping process, as described in the Background, or in an acidic sulfite cooking process.

With respect to the reaction of wood with alkali solutions, all components of wood are susceptible to degradation by strong alkaline conditions. At the elevated temperature of 140°C or greater that is typically utilized during Kraft wood pulping, the hemicelluloses and lignin are preferentially degraded by dilute alkaline solutions. Additionally, all components of wood can be oxidized by bleaching agents such as chlorine, sodium hypochlorite and hydrogen peroxide.

Pulping procedures, such as alkaline pulping, can be used to provide an alkaline wood pulp that is treated in accordance with the present invention to provide a composition useful for making lyocell fibers. Examples of a suitable alkaline pulping processes include the Kraft or soda process, without an acid prehydrolysis step or exposure to other acidic heterogeneous mixture conditions (i.e., reaction time, temperature and acid concentration) where cellulose glycosidic bonds are broken through (1) the rapid protonation of the glycosidic oxygen atom, (2) slow transfer of the positive charge to C—1 with consequent formation of a carbonium ion and fusion of the glycosidic bond and (3) rapid attack on the carbonium ion by water to give the free sugar. While a typical Kraft bleaching sequence containing a chlorine dioxide stage or multiple chlorine dioxide stages involves a pH less than 4 and a temperature greater than about 70° C, the combined heterogeneous mixture conditions of such stages are not suitable to induce substantial DP reduction in cellulose. By avoiding an acid pretreatment step prior to alkaline pulping, the overall cost of producing the alkaline pulped wood is reduced. Further, by avoiding the acid prehydrolysis the degradation of hemicellulose is reduced and the overall yield of the pulping process can be increased. Thus, as used herein the phrase alkaline pulp refers to pulp containing cellulose and hemicellulose that has not been subjected to any combination of acidic conditions or any other heterogeneous mixture conditions (i.e., reaction time, temperature, and acid

concentration) that would result in breaking of the cellulose glycosidic bonds before or during the pulping process wherein wood chips or other biomass is converted to fibers.

Characteristics of alkaline pulped wood suitable for use as a starting material in the practice of the present invention include a hemicellulose content of at least 7% by weight, preferably from 7% to about 30% by weight, more preferably from 7% to about 25% by weight, and most preferably from about 9% to about 20% by weight; an average D.P. of cellulose of from about 600 to about 1800; a kappa number less than about 40 preferably less than 30 and more preferably less than 25, and a copper number less than about 2.0, preferably less than 1.0. As used herein, the term "percent (or %) by weight" or "weight percent", or grammatical variants thereof, when applied to the hemicellulose or lignin content of pulp, means weight percentage relative to the dry weight of the pulp.

As shown in FIGURES 1A-1C, in the practice of the present invention, once starting material, such as softwood, has been converted to an alkaline pulp containing cellulose and hemicellulose, it is subjected to treatment in reactor whereby the average D.P. of the cellulose is reduced, without substantially reducing the hemicellulose content or increasing the copper number, to provide the compositions of the present invention. In this context, the term "without substantially reducing the hemicellulose content" means without reducing the hemicellulose content by more than about 50%, preferably not more than about 15%, and most preferably not more than about 5% during the D.P. reduction step. The term "degree of polymerization" (abbreviated as D.P.) refers to the number of D-glucose monomers in a cellulose molecule. Thus, the term "average degree of polymerization", or "average D.P.", refers to the average number of D-glucose molecules per cellulose polymer in a population of cellulose polymers. This D.P. reduction treatment can occur after the pulping process and before, after or substantially simultaneously with the bleaching process, if a bleaching step is utilized. In this context, the term "substantially simultaneously with" means that at least a portion of the D.P. reduction step occurs at the same time as at least a portion of the bleaching step. Preferably the average D.P. of the cellulose is reduced to a value within the range of from about 200 to about 1100; more preferably to a value within the range of from about 300 to about 1100; most preferably to a value of from about 400 to about 700. Unless stated otherwise, D.P. is determined by ASTM Test 1301—12. A D.P.